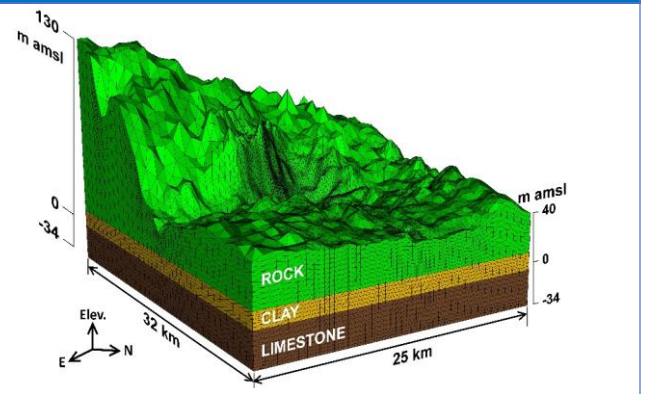
Numerical simulation of regional and local aquifer evolution in the Nobarya region, Egypt

Project summary



Client:	CURSA
Partner:	Aplus
Year:	2013-2014
Service:	Computer Modelling
Sector:	Water Resource Engineering
Project in numbers:	Regional 3D model: 146.275 DOF, Local 3D model: 438.774 DOF
Coding language:	Fortran90
Other details:	M3E-FLOW3D, SUTRA, Unsaturated flow model, Richards equation, Transport model, Al-Nobariya, Egypt

Abstract

The aim of the project is to simulate the evolution of aquifers at a regional and local scale with 3D Finite Elements models. The simulation at the regional scale was performed with the aid of M3E-FLOW3D, a three-dimensional groundwater flow model developed and updated by M3E team. At the local scale, the model was built using the SUTRA code, a three-dimensional groundwater flow and transport finite elements model simulation. The modeling results were included in a GIS database to promote data sharing with partners and stakeholders and improve the production of thematic maps.

Project description

The purpose of IMPROWARE (Innovative Means to PROtect WAter resources in the Mediterranean coastal areas through RE-injection of treated water) is the development of two demonstration projects, in Egypt and Tunisia, to: i) enhance the fresh recharge of coastal aquifers contaminated by saltwater intrusion and increase water availability for irrigation purposes by using recovery wastewaters properly brought to the required quality levels by purification plants; ii) derive examples of “best practices” and “lessons learned” from the action; and iii) disseminate the results within the ENPI Mediterranean region.

The objectives can be summarized in three principal points:

1) reducing the current over-exploitation of drinking groundwater and improve the economic development prospects of rural communities in the targeted regions by increasing water availability for agricultural activities;

2) investigating specific methodologies for using waste waters to recharge coastal aquifers in regions suffering from saltwater intrusion;

3) encouraging co-operation in the area of sustainable and integrated water management through capacity building, institutional strengthening and participation.

The modelling activities within IMPROWARE are focused on the Egyptian site.

Numerical models represent a powerful tool to predict the evolution of the groundwater flow and groundwater quality due to natural forcing factors (e.g., reduced natural recharge due to climate changes) and anthropogenic activities (groundwater pumping or recharge).

The study consists of two parts, which are briefly presented, namely:

- Regional model
- Local model

In the framework of this proposal, we have used the M3E-FLOW3D code, a state-of-the-art finite-element groundwater flow/transport simulator. The code allows for a complete three-dimensional representation of the multi-aquifer system, the fully transient, semi-transient and steady-state flow and transport processes and handle heterogeneous materials and solute properties, including conductivity, dispersivity, porosity, distribution coefficients, mass transfer coefficients, and decay constants.

The code is characterized by a pre-processing allowing for the discretization into FEs of very complex hydrogeological structures characterized by non-uniform geological horizons, lenses, local heterogeneities, and bedrocks. The flexibility guaranteed by FEs allows for the use of local grid refinements in areas of particular interest such as well fields, infiltration basins, hydraulic connection with surface water bodies, and recharge areas. The use of the state-of the-art HPC solvers developed by the M3E team allows for an efficient solution of very large models on multi-core parallel computers up to 10'000'000 nodes.
A reliable simulation of the effects of aquifer recharge (both by infiltration basins or wells) or groundwater pumping requires the accurate hydrogeological characterization of the subsurface system. This activity has been carried out by integrating in-situ investigation and numerical modelling. Various available data have been be collected and integrated to build the three-dimensional architecture for the hydrological model of the selected site: the litho-stratigraphy of the basin, with particular emphasis on the geometry of the aquifers; the hydrological and geomechanical properties of the aquifers and the intervening aquitards or semi-impermeable units (e.g., porosity, hydraulic conductivity, elastic storage, soil compressibility, etc.); the digital elevation model of the area and the geometry of the main drainage network; the climatic regime (e.g., temperature, wind, precipitation, solar radiation) over the last several years; the historical behavior (measurements and/or estimations) of the groundwater volumes pumped out from the subsurface, with the location of the wells, the intake depths; the records of the evolution of the pond surface developed over the years at Al-Nubariah.

This part describes the modeling activities and results of the groundwater flow and transport Finite Element (FE) model developed at the local scale (e.g. a dimension of the area comparable with the hydrogeological investigation and geophysical surveys performed in the framework of IMPROWARE) for the Al-Nobariya pilot site, northern Egypt.

The work has been performed through the following main steps:

1) selection of the model domain based on the available information;

2) definition of a realistic hydrogeological model from both literature-derived data and specific surveys;

3) acquisition of appropriate boundary conditions from the regional-scale groundwater flow model;

4) run of the density-dependent groundwater flow-transport model in steady-state conditions to define an appropriate initial state in terms of piezometric head and salt concentration for the transient simulation scenarios of artificial aquifer recharge (AR);

5) investigation of the AR effects for a number of scenarios developed to meet the project purposes;

6) analysis of the modelling results and conclusions.

The evaluation of modelling results is used to analyze a set of possible configurations for the groundwater artificial recharge reusing available wastewater from treatment plant.

Project outcome

The outcome of the project was a GIS database summarizing all the modeling results, along with the data collected from literature reviews in the two study sites of Egypt and Tunisia.

Reference

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